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ABSTRACT

This paper provides a prescriptive approach, i.e., a suggestion of what ought to be, the future of computer instruction in higher education. Discussed are: (1) computer capabilities and costs, in terms of hardware and software, and two major trends in computing that hold special promise for instruction with the computer: large centralized computing facilities, and small, inexpensive minicomputers; (2) the provision of computer service in terms of four choices: a centralized campus facility; decentralized campus facilities; regional networks; and commercial time-sharing service; (3) the provision of instructional materials, including the current situation, and the suggestion that commercial time-sharing systems and small, inexpensive computers could offer the means to use these materials that could be produced and distributed on the same basis as textbooks are now; and (4) how these developments would affect higher education. The paper concludes with recommendations for actions to be taken by (1) the federal government; (2) industry; and (3) administrators and faculty in higher education. (AF)

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Roger E. Levien

March 1971

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INSTRUCTIONAL USES OF THE COMPUTER IN HIGHER EDUCATION

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INTRODUCTION

The Carnegie Commission on Higher Education, chaired by Clark Kerr, was established in 1967 to study and make recommendations concerning the future of American higher education. In carrying out its charter the Commission has sponsored a number of studies of various aspects of the higher educational enterprise. One of their concerns has been the role that technology--especially computer technology--might play in extending access to quality higher education throughout the country and in raising instructional quality or reducing its cost. Consequently, early in 1969 the Commission requested Rand to undertake a study of instructional uses of the computer in higher education. We were to consider the ways in which the computer could be used, review the current state of use, and examine the possibilities and prospects for instructional uses in the future. Early in 1970 the National Science Foundation and Rand provided additional support for further work and for the convening of this conference. The final report of the study will be available in 1971. This paper is a preliminary report on the third aspect of Rand's study--an examination of the future of instructional uses of the computer in higher education.**

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This paper was presented at the Conference on Computers in Instruction: Their Future for Higher Education, held in Los Angeles, California, October 1970. It reports the findings of a study sponsored by the Carnegie Commission on Higher Education and the National Science Foundation.

**The conclusions of this study are directed explicitly to higher education. Quite different conclusions and recommendations might be warranted for elementary and secondary education.

Prediction Versus Prescription

There are two ways to approach estimates of the future: predictively and prescriptively. A *predictive study* attempts to estimate what *will be*, taking into account the probable developments in technology and institutions and seeking to discern the most likely outcome, but not suggesting actions that might make one or another outcome more probable. A *prescriptive study*, however, begins with an idea of what *ought to be* and attempts to make recommendations that will help to achieve that desired goal. Since one major objective of the Carnegie Commission-sponsored study has been to derive recommendations for action by higher education, industry, and government, we have adopted a prescriptive approach. The future of instructional use of the computer in higher education is not fixed and immutable. We can shape it to serve our objectives.

Objectives for Instructional Computer Use

What are those objectives? The answer to this question is not simple; but even to begin to discuss it adequately it is necessary to be more precise about the meaning of instructional uses of the computer. With regard to objectives, one categorization of those uses is especially important: that which distinguishes between instruction *about* and instruction *with* the computer.

Instruction about the computer occurs in fields such as engineering, business, mathematics, and computer science, in which the computer itself is the *subject* of study. There are, in fact, three subcategories of such use: *specialist* instruction, which serves those prospective engineers, programmers, analysts, and others who will devote their careers to some aspect of computing; *service* instruction, which serves prospective scientists, businessmen, and professionals who will use computer tools in their future careers; and *survey* instruction, which serves all students, who as citizens and consumers will have to be aware of the computer's benefits and dangers.

The need for instruction about the computer comes from outside higher education; it derives from the needs of society, in which the computer is widely used, for specialists trained in its use and for

a populace aware of its properties. Consequently, *the future of instruction about the computer in higher education depends on society's future needs for computer specialists, users, and literates.*

The objective of national policy concerning instruction about the computer, thus, should be to insure that higher education is providing adequate training of a sufficient number of persons to meet the national needs. The *relative* cost of computer use (as compared with other modes of instruction) in instruction about the computer is not a major question, since the computer must be a part of such instruction in most cases, just as expensive laboratory equipment is an essential part of teaching in the physical and biological sciences, engineering, and medicine. The *total* cost of computer use is, however, a major problem, especially in these times of expanding computer use and tight higher education budgets. To the extent that higher education is meeting an important national need through instruction about computers, then, some national subsidy program from industry or government might be warranted. However, this study has not been principally concerned with instruction about the computer. Our attention has been focused on the next category.

Instruction with the computer has the potential to change higher education significantly. In such uses the computer is being employed as a tool to assist the teacher or the learner during the instructional process. The computer may present tutorial or drill material, aid in the simulation or gaming of a complex process, assist in the solution of difficult practice problems, keep track of student progress, or give review tests and examinations.

The need for instruction with the computer comes from within higher education; it occurs because the computer possesses some advantage over alternative modes of instruction: teacher, textbook, television, or other technology. The advantage may be that it is more effective, or less costly, or some combination of both (including less effective, but also less costly). Consequently, *the future of instruction with the computer in higher education depends on its advantages relative to alternative modes of instruction.* This fact is often summed up by saying that the computer's use must be *cost-effective,* which means that for a particular use, as compared with alternatives, the computer provides the most satisfactory combination of cost and effectiveness.

The objectives of national policy concerning instruction with the computer, therefore, should not be to encourage the use of the computer for its own sake, but rather to see that access to the computer is possible wherever its use would be cost-effective *and* to see that its use is refined and improved so as to broaden the range of circumstances in which it can improve instruction. (These should be the objectives of national policy with regard to other modes of instruction as well.) The *relative* cost of computer use in instruction with the computer is a major question; the computer justifies itself only through advantages in cost and effectiveness. However, the *total* cost of computer use is not a major problem; since it is only one mode of instruction, there is no greater reason to subsidize its use than to subsidize any other mode. National policy might require the subsidy of higher educational instruction in general, but the choice of teaching method within that general subsidy would seem to be better left to the discipline, institution, and instructor.

The task faced by a prescriptive approach to the future of instruction with the computer, then, is to discern the major factors and alternatives that will affect the way in which the computer participates in the instructional process and to suggest those actions that would seem most likely to serve the objectives of national policy. The major factors and alternatives can be broken into four categories:

- o The computer's capabilities and costs.
- o The methods for providing computer service.
- o The methods for providing instructional materials.
- o The effects on higher education.

This paper will describe our study's conclusions about the likely developments in each of those categories and then suggest some actions intended to bring about the fullest realization of the computer's potential for efficient participation in the instructional process.

COMPUTER CAPABILITIES AND COSTS

Our major conclusion with regard to the likely future state of the computer art is that it will not be a problem or impediment to the computer's effective use in instruction.

Hardware

Computer hardware capabilities and costs are already, and will continue to be, completely adequate to support a sufficient number of "interesting" instructional uses of the computer. Of course, as capabilities increase and costs decrease, a wider and wider range of uses will become feasible, but the effect will be to move us further along a continuum of use along which we have already advanced, not to cause a sharp increment in the attractiveness of computer use.

Most of the desirable and anticipated advances in computer hardware are likely to occur as a result of the demands of uses outside of education. The two most critical areas for education are terminal devices and communications. While available terminals do not yet satisfy all of the needs of educational use, the competition and rate of improvement in terminals is high. Communication problems, especially the need for reliable and inexpensive telephone connection between campus terminals and remote computers, may prove more serious. Nevertheless, there are developments, both administrative and technological, that promise to ease these problems during the next few years.

Software

The situation with respect to software capabilities and costs is similar. We already possess the programming tools to do many (not all) interesting things with the computer as an aid to instruction. The current generation of operating systems and programming languages is completely satisfactory to support a wide range of effective instructional uses. Indeed, they provide far more capability than has been used. We must learn how to exploit that potential more fully.

There is one direction of software development not yet being explored vigorously that warrants further effort in the service of education: development of software tools to aid in the flexible employment of the computer as a medium. The computer when connected to a television-like terminal becomes a medium that differs from text, television, film, or phonograph in its ability to intermix text, still pictures, and motion pictures and in its capacity to ask for and respond to human guidance

in determining the sequence of images and content to be displayed. This flexibility and responsiveness might be employed to create materials that each user could individualize by tracing his own path through a complex, highly interlinked network of text or pictorial segments. (This concept has been suggested, described, and explored by Theodor Nelson, who coined the term "hypertext" to describe the network of text or pictorial segments.)

Two Major Trends

In addition to the satisfactory basis for instructional use provided by the current and likely future overall computer state of the art, two major trends in computing hold out special promise for instruction with the computer. The first is the development of *large, centralized computing facilities* whose use is shared by many remotely situated customers linked to the computer via telephone lines. The second is the development of *small, cheap minicomputers* that can be programmed via an easily exchangeable medium such as magnetic-tape cassettes like those used in sound recording. Each of these modes of use--highly centralized and highly decentralized, as well as combinations of the two--offers considerable potential advantage for instructional use, because each offers a convenient way to disseminate instructional materials beyond their place of origin: storage of the materials in the large central computer automatically makes them available to any of the remotely situated users; cassettes containing instructional materials for the minicomputers can be distributed and sold or rented like books or records. These two technological developments, then, provide the basis for creating a *market* for computer-based instructional materials not unlike the one that exists for textbooks. As we shall explain shortly, the creation of such a market seems to us to be the critical step in achieving the desirable level of computer use in instruction.

PROVISION OF COMPUTER SERVICE

We can now turn our attention to the campus and consider the first of two interlinked questions: How will computer service be provided? How will computer-based instructional materials be provided?

Computer service is needed on campus for several categories of use: administration, research, and instruction. Frequently, the same service meets all three needs. In many instances, however, separate services for administration or specialized research uses exist. In this discussion the objective will be to determine the desirable means of providing service for instruction; the other uses will not be considered.

Consider a college or university seeking computer service. It has four choices:

- o Centralized campus facility--serving all its needs with a centrally managed computer.
- o Decentralized campus facilities--letting each user or group of users acquire its own computer.
- o Regional networks--sharing the use of a computer managed in conjunction with a group of other institutions.
- o Commercial time-sharing service--sharing the use of a computer managed by a commercial computer service organization.

Since we have put aside administrative and research uses, we can consider these four alternatives on the basis of a single criterion: Which will provide the best instructional service? But instructional use of the computer requires two things:

1. Computer service.
2. Instructional materials.

The core of the argument we make in this study is that these two things cannot be separated. Choices made with respect to one must take the other into account. Thus, in choosing a mode of providing computer service we must be guided by the implications for the provision of instructional materials. To see how this might be done, let us consider each of the four choices above.

Centralized Campus Facility

The centralized campus facility is the most common means of providing computer service at present. Experience leads us to expect that most of these facilities will be idiosyncratic and non-standard. That

is, only a very few campuses will have computer facilities similar enough to permit easy exchange of programs--that is, instructional materials--among them. As a result, most instructional materials will be locally produced for local use; instructional computer use will remain a "cottage industry" with little cumulation, few incentives for authors, duplication of effort, and wide disparities among campuses in their access to effective instructional computer uses.

Decentralized Campus Facility

The decentralized campus facility has ordinarily been considered a less satisfactory situation than the centralized facility. It adds intracampus variations among computer facilities to the problems of intercampus differences. However, if the previously noted trend towards small, cheap computers continues to develop, this situation may change; for there are several reasons to expect such small computers to become standardized to a degree that their larger antecedents have not been. First, they are less likely to have associated staffs of computer scientists and professional programmers who know how to introduce local variations into hardware and software. Second, they are likely to be produced in a volume and by technologies that will favor standardization. Third, they will need a repertoire of prepared programs available on a standardized cassette (or other exchangeable medium) to serve the non-specialist users who will necessarily make up most of the market. In other words, the small computer may become a kind of "intelligent record-player" serviced by a market in standardized cassette programs the way the conventional record-player is serviced by the market in stereo records and cassettes. Should this occur, then each campus might have many computers for instructional purposes distributed as television sets or tape players are now. Together they would constitute a significant market for instructional materials made available in tape cassettes. These small computers might also communicate via telephone lines with larger computers when special functions, like access to large data bases or extensive computations, are required. However, until mass-produced, standardized, cheap computers become available, decentralized facilities are probably not the best choice for a college interested in instructional uses.

Regional Network

The regional network is a third possibility. It has the obvious advantage of providing access for each member institution to facilities of a capability and cost beyond those available to it independently. An even more important advantage for instructional use is that it provides a mechanism for the intercampus distribution of instructional materials. Physics professors at several institutions, for example, can contribute to a common pool of programs and share, rather than duplicate, each other's work. While such regional networks thereby offer considerable advantage over centralized campus facilities, they have two drawbacks. First, there is as little standardization among network facilities as there is among single campus facilities. Thus, while exchange within a network is eased, exchange between networks remains difficult. Second, the networks, as nonprofit organizations, have not developed the extensive and vigorous sales and marketing activities needed to encourage the widespread development and use of computer-based instructional materials, nor can they easily acquire the funds to do so.

Commercial Time-Sharing Service

The fourth possibility is the commercial time-sharing service. A number of schools are already making use of such services to supplement local facilities. Ordinarily they are used as sources of "raw" computer power; that is, they serve users who write their own programs in a conventional programming language. Some services also provide a library of common computational programs. However, a recent innovation holds considerable potential for instructional use of such services. Several services now collect fees for the use of programs stored in their program libraries; part of that fee goes to the program author as a *royalty*. Thus, commercial time-sharing services provide the mechanism for marketing computer-based instructional materials (and, of course, other programmed services) and for financially rewarding their authors. They also solve two other problems: nationwide access and standardization. The larger services, for example, link computers at several places around the country through communication lines and connect users to whichever computer has available capacity or the desired stored program

materials. Thus, each service may make its materials available to many campus users around the country. Conversely, each campus user may gain access through his local terminal to many different time-sharing services. As long as each service provides messages compatible with his terminal (and that is not generally a problem), the user of programmed instructional materials is oblivious to the type of computer and programming language serving him.

Conclusion

Thus, of the four possible ways to provide instructional computer service to the campus, two have special promise for promoting the widespread production and dissemination of instructional materials: small, cheap decentralized computers programmed via standardized cassette, and commercial time-sharing services with royalty-paying program libraries. While the former lies somewhat in the future, the latter is here, although not yet widely used for instructional purposes.

PROVISION OF INSTRUCTIONAL MATERIALS

How will those materials be provided? There are two problems: Who will produce the materials? Who will distribute them?

Current Situation

Let us look at the current situation. As noted earlier, it might be best characterized as cottage industry. Materials are locally produced and locally used. The wheel--or, rather, the harmonic oscillator--is reinvented many times on many campuses. Individual authors rarely employ or build upon the work of others; there is little cumulation of materials and techniques. What dissemination and exchange of information occurs is voluntary and episodic; it relies on the enthusiasm and energy of both author and user, thus limiting the potential audience. A handful of national conferences, a small number of newsletters, and sections in several scientific journals constitute the extant communication system. The prospective user sees no salesman, receives no aid in putting the material into use. Moreover, the prospective author of

computer-based instructional materials faces only disincentives. Since there is no commercial distribution, he anticipates no financial rewards. And since the materials are unlikely to reach his colleagues on other campuses, he is unlikely to reap professional prestige for his efforts. The administration is not even likely to reduce his teaching load or to reward him with promotion or tenure for his efforts. He would be better off writing a research paper or a textbook.

How might the situation be improved? Well, we have a model of a medium in which instructional materials are continually being produced and improved, in which cumulation of content and method occurs, in which there is widespread and effective dissemination, and in which strong incentives for authorship operate: the textbook.

The Textbook Model

The textbook is ordinarily produced by a faculty author, a practicing member of the subject discipline--often a respected scholar. His incentives are both financial (he stands a chance of doing very well on royalties) and professional (he can gain the stature and visibility in his discipline that provide both upward and sideward mobility). Others will be seeking the same rewards; thus there are likely to be a number of competing texts, offering different approaches and building upon previous texts.

Textbook distribution is in the hands, usually, of commercial publishers, who see that each text is appropriately designed and printed, who publicize the text, and who deploy a force of salesmen to make sure that each prospective user is aware of the text's strengths. They have strong incentives to see that the text is widely adopted and used.

Textbook selection is made by the faculty user who must choose among texts employing a multiplicity of approaches and content. Frequently, he chooses several texts. Often, he individualizes his course by adding his own locally printed materials. Sometimes, he becomes a text author himself.

Can this situation be matched for computer-based instructional materials? Can we create a situation in which instructional use of the computer advances through the cumulative contribution of the thousands

of prospective authors whose energies are enlisted by a system that provides opportunity and incentives? We believe that we can, and that the two possibilities described earlier--commercial time-sharing systems and small, cheap computers--offer the means.

Commercial Time-Sharing Systems

Let's consider the commercial time-sharing system first. It might work like this:

Materials would be created by faculty authors (and student assistants or programmers) at many different campuses. Initially, these materials might be closely linked to existing texts; they might include problem sets, demonstrations, simulations, tutorials, and drills tied to text material.

Publishers would acquire the materials, edit and refine them, and place them into the program libraries of one or more commercial time-sharing services under a royalty payment arrangement. Each publisher would have a collection of programs in a given subject area stored in the program library. Thus, there might be the McGraw-Hill Economics Library, which would include tens of programs related to McGraw-Hill's economics textbooks.

The publisher's salesmen would demonstrate computer-based materials along with textbooks to the faculty members they visited on campus. A salesman might carry a portable computer terminal and leave it with the instructor to permit him to try each of the available materials.

The instructor could then choose from the program library those items he would like his students to use and arrange with the local time-sharing service for the installation of terminals (unless the school already had them) for their use. To further individualize the course he could develop some of his own materials and store them in the local service for his students' use as well. And once the terminals were on campus, they could be used to gain access to other publishers' materials: Wiley might have a competing economics program library, Van Nostrand might have one in physics, and so on.

Why would authors produce materials? Well, first, with widespread access, royalty payments could become quite significant. Second, the

materials would be signed and their wide distribution could gain for their authors the reputation that translates into professional advancement. And, third, as the use of such materials grows, their development and refinement will become an inherent part of the teaching process, as the production of class notes and textbooks is now.

Three further aspects of this possibility deserve exploration. The first is, How will instructional use of the computer grow--institution-by-institution or discipline-by-discipline? Numerous attempts have been made to introduce widespread use of an instructional technology on a single campus. Most have failed to have significant effect. The University of California Irvine campus, for example, began with ambitious objectives in instructional computer use. The achievements have fallen far short of the ambition. A major reason, it seems to us, is failure to recognize that the college or university instructor shapes his course's content and method on the basis of what is considered appropriate by his discipline colleagues on other campuses far more than on the basis of what is being done by his institutional colleagues on the same campus. Thus, the appropriate unit of instructional innovation is the discipline. Widespread introduction of the computer into instructional use will require the active participation of each of the major disciplines. In some disciplines such participation is already occurring. The Commission on College Physics has been active in development of computer uses in physics; groups in chemistry, engineering, and business administration have also engaged in information exchange activities. However, these efforts will have to be expanded in scope, in scale, and in coverage of the disciplines and linked more closely to "publishers" if they are to bring about widespread change.

The second is, Can a truly competitive market develop? Once a sufficient scale of use occurs, there should be little trouble attracting sufficient authorship to insure up-to-date, continually improving materials. The returns from royalties will likely be as great as or greater than those that reward textbook authors. Nor is copyright or patent protection likely to be a problem. The materials can be stored in a time-sharing system in such a way that access to their use can be gained, but not to the programs themselves--except at very great

difficulty. Moreover, the creativity and rate of change are likely to be so great in the early years of use, as authors learn how to exploit the medium effectively, that copyright or patent protection would be of little use.

The third is, Who pays for the instructional use of the computer? Even when questions of cost and effectiveness are answered favorably, instructional computer use faces another, more subtle difficulty. It would be logical to expect the charges for instructional uses of the computer to come from the instructional budgets of the various academic departments. Yet how many department chairmen are likely to spend that budget on computer use, no matter how effective, in preference to faculty salaries? A fellow faculty member, after all, not only teaches, but does research, counsels students, and participates in the social life of the department. It is a rare chairman or dean who, given the choice, would opt for the machine instead of the man, even if the latter were less effective. As long as instructional computer use must be supported from departmentally allocated instructional budgets, it is not likely to gain widespread acceptance. It is instructive in this connection to note that in the case of the only instructional technology to gain widespread acceptance and use--the textbook--it is the student who normally pays. We expect that some similar arrangement may develop in the case of computer use as well. In that regard, the second of the promising alternatives--the cassette-programmed minicomputer--has some advantages.

Small Computers

The institutions for creating and producing instructional materials for the small computer system would be similar to those for the system based on centralized time-shared computers. However, each campus would have a number of standardized minicomputers into which instructional programs on cassettes would be inserted. The cassettes would be sold or rented--to students--in the same way books or records are now sold through local stores. Thus, distribution would be via cassette instead of via telephone access to a central program storage. However, we can imagine that the computers themselves would be paid for by the college or

university, as a capital expense and not from department funds, and the students would bear the expense only of the instructional materials. Similar division of costs between institution and student are technically possible in the centralized time-shared computer case, but various practical difficulties make it seem less likely to occur.

EFFECTS ON HIGHER EDUCATION

Now we can turn to the last question: How would these developments affect higher education? Will instruction with the computer grow rapidly and revolutionize college teaching? Will it play a part in all courses and disciplines or will it be limited to a specialized part of the curriculum? Will its influence expand beyond the campus? Our study has led us to believe that the effects on higher education will be gradual, evolutionary, cumulative, supplementary, subsidiary, and paced by computer developments off-campus. Let me explain.

The computer's effect on instruction will be evolutionary, not revolutionary. Revolution will not occur because we do not now know enough, and we are not likely to be able to learn enough soon, to develop sufficient, effective instructional materials to change traditional practice in more than a very few courses. This will be true even if computer costs plummet rapidly. In addition, revolution through computer use would require considerable change in the organization and staffing of existing higher education institutions; that is not likely to occur short of revolutionary changes in the administration, sociology, and financing of higher education.* However, if a viable, national market for instructional materials is created, the chance of a gradual, evolutionary growth of instructional computer uses occurring is good. In the beginning, materials will be created for those sections of those courses for which the possibilities and techniques are most evident and in which the faculty interest is likely to be greatest. Problem sets, laboratory simulations, games, demonstrations, and drill for physics,

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*Some would argue that these are in the process of occurring (independently of the computer). Those changes that are taking place, however, do not seem to be making it easier for computer use to grow; quite the contrary.

statistics, chemistry, engineering, business, and foreign languages are promising candidates. As use of such materials spreads, as the incentives and opportunities for authorship grow, and as creative instructors across the country get the chance to experiment with computer tools, we have little doubt that many additional types of use and many uses in additional subjects will develop. As these materials cumulate, opportunities will arise to join them together in larger and larger segments. Finally, after a number of years, enough material and experience will have come together to enable computer-based courses to be created in a wide range of subjects. At that point, complementary changes in institutional structure and program will become desirable and feasible. The revolution will have evolved.

The computer's best chance for early advantage is in those parts of the curriculum that are in one way or another subsidiary, those parts that the faculty does not like to teach. For example, a reasonable market could develop in foreign language training for those who must meet doctoral or other requirements. Other possibilities exist in statistics for social scientists, computer programming, remedial subjects, and so on. In the courses of major interest, the computer's use is likely to be supplementary--that is, it will add to the quality (and cost) of the course, rather than substitute for some other means of instruction. In fact, we do not see great opportunities for cost savings until the evolution noted above occurs and changes in the structure and staffing of higher education can take place.

Instructional use of the computer may advance more rapidly outside of the campus than on it. The same computer technologies available to the campus--centralized time-shared computers and minicomputers--will be available to business and, not unlikely, to individual homes. The institutional constraints on instructional uses in such environments will be less than those on the campus. It is possible, therefore, that development of computer-based instruction will take place most rapidly outside of higher education and that the campus will be in the position of responding to those developments.

RECOMMENDATIONS

Where do these findings lead us? What recommendations for action by higher education, industry, and government do we have? Recall that we argued that the objectives of national policy concerning instruction with the computer should be:

- To see that access to the computer is possible wherever its use would be cost-effective.
- To see that its use is refined and improved so as to broaden the range of circumstances in which it can improve instruction.

The study has led us to feel that these objectives will be best achieved by creating a market for computer-based instructional materials through actions that take advantage of opportunities presented by new developments in computer technology. Thus, the following recommendations are aimed at the creation of such a market.

Government

The Federal government should:

- Support R&D on hardware and software of special importance for instructional uses, including:
  1. *Terminals* that are inexpensive, easy to use, durable, and reliable;
  2. *Small computers* that can be programmed via a standardized, exchangeable medium and can be used with an inexpensive terminal;
  3. *Communications* among computers and between computers and terminals that are inexpensive and reliable;
  4. *Software* that makes more of the computer's flexibility as a medium available to author and user.
- Support the start-up phase of instructional materials development within discipline-based groupings. These should be a part of wider activities to develop materials using other media as well, and should include realistic plans for dissemination beyond the local facilities. They should be designed to become self-sustaining as use of the materials grows.

- o Continue to support experiments in various ways to provide computer service and instructional materials to campuses, with special attention to the latter and to the gathering of careful, comparable cost and effectiveness data. Commercial time-sharing services and small computers should be two of the models tried and the discipline-based materials development efforts should be linked to those experiments when possible.
- o Congress and the regulatory agencies should pay special attention to the needs of instructional uses of the computer (and to the need to create a viable market for instructional materials) when considering copyright and patent laws and regulation of the communications industry.

Industry

The several branches of industry having a potential interest in instructional uses of the computer should, first, pay far greater attention than they currently do to the potential of the educational market and, second, recognize that the instructional market is a market for materials (not raw computer power) and must be treated differently from the research or administrative market in education. Like the LP record market, both the equipment and the materials producers have a self-interest in standarization, interchangeability, and the volume and variety of materials provided by a multiplicity of producers. They should vigorously invest in the development of instructional uses of the computer.

The *hardware manufacturers* should focus their efforts on providing the standardized, reliable, and inexpensive hardware on which the materials will be used and on developing the operating systems and languages that will make the computer's flexibility available to authors and users. Hardware needs are greatest in terminals, small computers with exchangeable media, and communications facilities.

The *time-sharing services* should seek to develop the potential of the instructional market by:

- o Making special contracting arrangements with higher educational institutions that take advantage of the nature of such uses to lower costs;

- o Developing the hardware and software facilities to build, maintain, and use large libraries of instructional materials on a fee-for-use basis;
- o Cooperating with publishers and faculty authors to build libraries of instructional materials;
- o Seeking terminal and communications compatibility with other time-sharing firms so that the campus user will be able to use a multiplicity of sources.

The *publishers* should concentrate on developing the means for facilitating authorship, for editing and refining the author's initial product, for distributing programs, and for marketing. Initially they should concentrate on a wide variety of supplementary materials (relating to existing texts) for subjects such as physics, business, economics, engineering, statistics, and chemistry. They should cooperate with a variety of time-sharing services and small computer manufacturers until the market settles down. They should engage respected men in the disciplines in the production and selection of materials through cooperation with discipline-based commissions and through formation of editorial advisory boards.

HIGHER EDUCATION

The two groups to whom recommendations are appropriate are the administration and the faculty.

Administrators should seek to create an environment in which the computer's potential to assist in the instructional process can be explored free from extraneous impediments and subject to positive support. Among the steps that can be taken are:

- o Encouragement of faculty participation in experiments with and development of computer uses by providing teaching time to develop materials and promotion rewards for those who succeed;
- o Encouragement of cooperative efforts with other institutions in which instructional materials are shared;
- o Selection of modes of computer service for instructional purposes that facilitate the sharing of instructional materials with other institutions;

- o Assignment of a portion of the instructional budget to support the development of computer materials that will be
  1. Subject to careful cost and effectiveness evaluations,
  2. Designed for use on other campuses,
  3. Feasible and acceptable for use on the local campus.

Faculty should seek to develop effective uses of the computer to improve instruction that

- o Are suitable for more than local use;
- o Make full and imaginative use of the computer's capacity;
- o Draw upon the skills and experience of other faculty in the same and related disciplines.

To this end, faculty within a discipline should encourage the formation of discipline-wide groups to develop instructional materials jointly.